Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft
Institut für Physik der Atmosphäre

Multi-scale investigation of aviation impact on atmosphere and climate with MECO(n)

Sigrun Matthes[1], Patrick Jöckel[1], Mariano Mertens[1], Pascal Frerebeau[1], Helmut Ziereis[1], Volker Grewe[1], and Astrid Kerkweg[2]

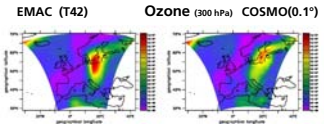
(1) DLR Institute of Atmospheric Physics, Oberpfaffenhofen, Germany (2) Institute of Atmospheric Physics, Johannes Gutenberg University of Mainz, Germany

Abstract

- **Aviation emission** have an influence on atmospheric composition and climate on regional and global scales. Atmospheric measurements from research aircraft aim to study and detect aviation influence in key species. Dedicated modelling studies need to support measurements by simulating physical and chemical processes relevant for the atmospheric fate of aviation emissions.
- Here, we use the **modular global-regional chemistry-climate-model MECO(n)** (MESSy-fied ECHAM and COSMO models nested n-times) describing atmospheric chemistry to investigate in detail the chemical and pysical impacts of aviation emissions on regional and global scales.
- For an efficient operational setup of our model simulation technical work focusses on **integration in a RCE environment** allowing a standardization of routine operation.
- With our regional **COSMO nests** we put particular focus on two regions: the North Atlantic Flight Corridor (NAFC) and the Southern Asian region.
- We use MESSy modules which allow direct **comparison** of **model data** with **observational data**, with a particular focus on in-service aircraft measurements, e.g. MOZAIC, CARIBIC, IAGOS. Such analyses allow evaluating modelled and observed atmospheric concentrations and determining the influence of aviation emissions on measurements.

Modelling process chain and coupling

- For an efficient design of our operational modelling chain we use **remote component environment** RCE which allows client and host structures on distributed hosts,. e.g. to access ECMWF input data (meteorological re-analysis), to run the MECO(n) system, and to generate and provide user-specific output.
- Individual **instances** (EMAC, COSMO) from within one MECO(n) cascade *(see table below)* communicate via a client-server-approach directly (point-to-point) with each other. Communication is via "single-sided non-blocking communication" based on "Message Passing Interface (MPI)".
- EMAC and COSMO/MESSy are **parallelized** following a horizontal "domain-decomposition" including distributed memory.



Overview on model instances

Model	Instance	Grid	Level	t [min]	ScaleT	SF Mem
EMAC	T42L90MA	128 x 64	90	12	1	1
COSMO	0,5° NAFC	120 x 80	40	2	3,13	0,52
COSMO	0,5° ASIA	120 x 80	40	2	3,13	0,52

Motivation - COSMO nests in EMAC

Requirements for design of model simulations to best support aircraft-based atmospheric observations are manifold and sometimes conflicting:

- High spatial and temporal resolution of model representation
- Short duration of simulations, computationally fast
- Complex representation of considered species and processes

We apply the **nesting technique** to combine **high spatial resolution** in specific areas of interest with a **global** representation of the chemistry-climate-atmosphere-ocean system.

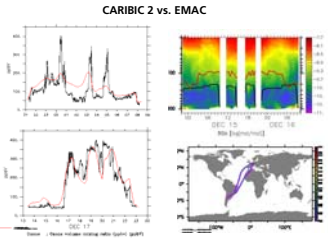


Figure: *Comparison of observation data CARIBIC-2 (ozone data from Andreas Zahn, KIT) with EMAC2 data.*

Objectives of AP 4300 in WeCare are

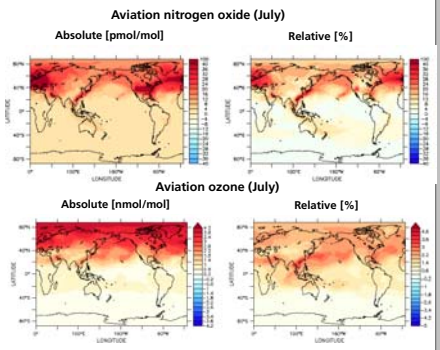
(1) to develop an operational modelling system for supporting aircraft measurement (feasibility study based on campaign data, and uncertainties);

(2) to help designing a campaign for proof of evidence of aviation impact (NO_x-O3); and

(3) to explore comprehensive forecast concepts for measurement trajectory planning.

MECO(n) – MESSY – EMAC – COSMO

- The highly structured **Modular Earth Submodel System (MESSy)** allows using specific submodules required for investigation. In our simulations we use gas phase chemistry calculated with the chemistry submodel consistently from the surface to the stratosphere. The applied chemical mechanism allows including full stratospheric and tropospheric complexity.
- Identical **chemical setup** in global model **EMAC** and regional **COSMO** nests, including a 1-way online coupling of meteorological and chemical species between regional nests and global model.



Figure

Absolute and relative aviation contribution to atmospheric concentration of ozone O_3 and nitrogen oxides NO_x in flight altitude (monthly mean)

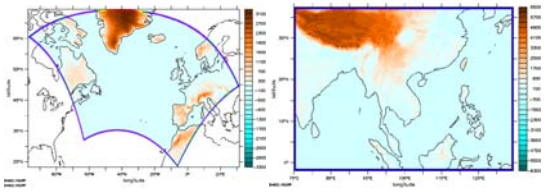
REACT4C FP7

Regional COSMO nests: North Atlantic (NAFC) & East Asia (EA)

- Regional COSMO nests in EMAC focus on two geographic regions: the North Atlantic Flight Corridor (NAFC) and the Southern Asian (EA) region.

North Atlantic Flight Corridor (NAFC)

East Asia (EA)



Figure

Regional COSMO in global EMAC domain, grid 120x80 with horizontal resolution of 0.5° x 0.5° latitude vs. longitude. Height of surface is indicated in meter.

Project objectives – Conclusions

- We present **concentration change patterns**, with particular focus on nitrogen oxide and ozone concentration changes in the UTLS region to demonstrate atmospheric impact of aviation.
- With the analysis we can assess to what extent **observational platforms** systematically deviate from meteorological mean values due to aircraft trajectory planning, and tactical decisions, e.g. cloud avoidance.
- Detailed knowledge on **fate of emissions** and **climate sensitivity** of the atmosphere in terms of the space and time dependence of the impact helps to develop a measurement strategy to detect aviation impact in the atmosphere.
- Overall objective is to help to **provide proof of evidence** of atmospheric impact of aviation emissions by using aircraft based measurements.
- Analysis of **measurement campaigns** from national research aircraft HALO can be supported.

Research projects - REACT4C & WeCare

Within the EU project REACT4C (coordinated by the author of this study) a multi-model assessment was performed to analyse and quantify atmospheric impact of aviation emissions (Aeronautics, FP7, Grant No. 233772) using EMAC in QCTM mode. WeCare is a four-year DLR collaborative project in aeronautics which started in 2013, comprising research to identify mitigation potential for aviation climate impact. For the integration into the Remote Component Environment (RCE) special thanks go to Doreen Seider, Jan Flinke, and André Zur from the DLR Facility Simulation and Software Technology , Cologne, Germany.